

PATENT ABSTRACTS OF JAPAN

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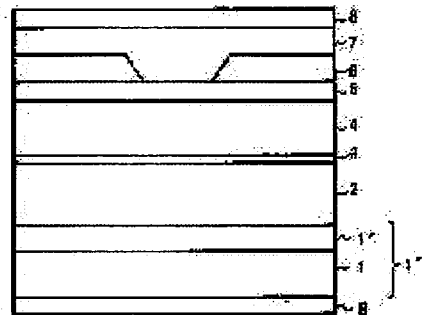
(54) SEMICONDUCTOR LASER ELEMENT

(57)Abstract:

PURPOSE: To realize operation in the oscillation wavelength of $0.5\mu\text{m}$ band at a room temperature by forming a double heterostructure consisting of mixed crystals of $(\text{AlGa})_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0.51 < \alpha \leq 0.73$) on a semiconductor substrate via a buffer layer which eliminates misalignment of lattice of such crystals.

CONSTITUTION: In a short-wavelength and visible semiconductor laser element which is suitable as a light source for optical information terminal or optical information processing, double heterostructures 2 to 4 consisting of mixed crystals of $(\text{AlGa})_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0.51 < \alpha \leq 0.73$) are formed on a semiconductor substrate 1 via a buffer layer 1 which eliminates misalignment of lattices of these crystals. The optical waveguide layers 2, 4 of the double heterostructures 2 to 4 are formed of $(\text{Al}_y\text{Ga}_{1-y})_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0 < y \leq 1$, $0.51 < \alpha \leq 0.73$), while the light emitting active layer 3 is formed of $(\text{AlGa}_{1-z})_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0 < z \leq y$, $0.51 < \alpha \leq 0.73$).

Therefore, a stripe structure which guides the light beam using difference of gain or refractive index can be manufactured and thereby laser oscillation in $0.5\mu\text{m}$ band can be obtained under the room temperature.



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CLAIMS

[Claim(s)]

[Claim 1] A double hetero structure which comprises a $(\text{AlGa})_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0.51 < \alpha \leq 0.73$) mix crystal on a semiconductor substrate, Form via a buffer layer which cancels both stacking fault, and a lightguide of the above-mentioned double hetero structure comprises $(\text{aluminum}_y\text{Ga}_{1-y})_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0 < y \leq 1 - 0.51 < \alpha \leq 0.73$), A semiconductor laser element, wherein a luminescence active layer comprises $(\text{aluminum}_z\text{Ga}_{1-z})_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0 < z < y$, $0.51 < \alpha \leq 0.73$).

[Claim 2] The above-mentioned semiconductor substrate comprises GaAs, the above-mentioned buffer layer comprises $\text{GaAs}_{1-x}\text{P}_x$, and the presentation X sets the above-mentioned GaAs substrate side side to zero, and is becoming large gradually in a thickness direction, The semiconductor laser element according to claim 1 used as X which carries out lattice matching to this layer by the lightguide side of the above-mentioned double hetero structure.

[Claim 3] The above-mentioned semiconductor substrate comprises GaAs, The above-mentioned buffer layer receives this GaAs substrate. . Carry out lattice matching. $(\text{aluminum}_{\beta}\text{Ga}_{1-\beta})$ The semiconductor laser element according to claim 1 which comprises a strained layer superlattice layer which consists of periodical structure of a $_{0.51}\text{In}_{0.49}\text{P}$ ($0 \leq \beta \leq 1$) layer and a $_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0 \leq \beta \leq 1$) layer which produces a stacking fault $(\text{aluminum}_{\beta}\text{Ga}_{1-\beta})$.

[Claim 4] The semiconductor laser element according to claim 2 which provided superlattice layers which consist of periodical structure of a $_{\alpha}\text{In}_{1-\alpha}\text{P}$ layer and a $(\text{aluminum}_y\text{Ga}_{1-y})_{\alpha}\text{In}_{1-\alpha}\text{P}$ layer between the above-mentioned $\text{GaAs}_{1-x}\text{P}_x$ layer and the above-mentioned lightguide.

[Claim 5] The semiconductor laser element according to any one of claims 1 to 4 whose presentation alpha of the above-mentioned lightguide and a luminescence active layer is 0.7.

[Claim 6] The semiconductor laser element according to claim 2 or 4 whose top layer of the above-mentioned $\text{GaAs}_{1-x}\text{P}_x$ mix crystal the presentation alpha of the above-mentioned lightguide and a luminescence active layer is 0.7, and is the presentation X= 0.4.

[Claim 7] A crystal face of the above-mentioned GaAs substrate is from a field (100) or (100) a field. [110] [-1-10] a direction — or [1-10] [-110] The semiconductor laser element according to any one of claims 1 to 6 which is a leaning crystal face or (110) a field up to 54.7 degrees at a direction as for an angle degree.

[Claim 8] The semiconductor laser element according to any one of claims 1 to 7 by which an impurity of the p type [active layer / above-mentioned / luminescence] or a n type is doped.

[Claim 9] The above-mentioned luminescence active layer, $(\text{aluminum}_{z_1}\text{Ga}_{1-z_1})_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0 < z_1 < y$) single quantum well layer, a $(\text{aluminum}_{z_2}\text{Ga}_{1-z_2})_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0 < z_1 < z_2 < y$) lightguide. The semiconductor laser element according to any one of claims 1 to 7 which comprises established single quantum well structure.

[Claim 10] The above-mentioned luminescence active layer, $(\text{aluminum}_{z_1}\text{Ga}_{1-z_1})_{\alpha}\text{In}_{1-\alpha}\text{P}$

($0 \leq z_1 < y$) quantum well layer and a $(\text{aluminum}_{z_2}\text{Ga}_{1-z_2})^\alpha \text{In}_{1-\alpha} \text{P}$ ($0 \leq z_1 < z_2 < y$) quantum barrier layer.

The semiconductor laser element according to any one of claims 1 to 7 which comprises multiple quantum well structure established repeatedly.

[Claim 11]The semiconductor laser element according to claim 9 or 10 by which an impurity of the p type [active layer / above-mentioned / luminescence] or a n type is doped uniformly.

[Claim 12]The semiconductor laser element according to claim 9 by which abnormal-conditions doping of the impurity of a p type or a n type is carried out at a lightguide in the above-mentioned single quantum well structure.

[Claim 13]The semiconductor laser element according to claim 10 by which abnormal-conditions doping of the impurity of a p type or a n type is carried out at a quantum barrier layer in the above-mentioned multiple quantum well structure.

[Claim 14]The semiconductor laser element according to claim 8, 11, 12, or 13 whose above-mentioned impurity concentration of a p type or a n type is the range of $5 \times 10^{17} - 2 \times 10^{18} \text{cm}^{-3}$.

[Claim 15]The semiconductor laser element according to claim 14 which the p type above-mentioned impurity kind becomes from Zn, Mg, or Be.

[Claim 16]The semiconductor laser element according to claim 14 to which the n type above-mentioned impurity kind changes from Si or Se.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Industrial Application]This invention relates to a short wavelength visible semiconductor laser element suitable for a light information terminal or the light source for optical information processing.

[0002]

[Description of the Prior Art]The conventional short wavelength visible semiconductor laser element for example, the Japan journal applied physics. the 1990 29th ** Lth — 1669 pages to the Lth — as discussed by 1671 pages (Jpn J.Appl.Phys.Lett. 29(1990)pp.L1669–L1671),It realizes by the $(\text{AlGa})_{0.5}\text{In}_{0.5}\text{P}$ mix crystal system which carried out lattice matching to the GaAs substrate. A continuous action oscillation wavelength [/ near / the / the room temperature] is 630 nm.

[0003]

[Problem(s) to be Solved by the Invention]However, the AlGaInP system semiconductor laser element which operates with the oscillation wavelength of a 0.5–micrometer belt in a room temperature is not reported.

[0004]An object of this invention is to provide the AlGaInP system semiconductor laser element which operates with the oscillation wavelength of a 0.5–micrometer belt in a room temperature.

[0005]

[Means for Solving the Problem]The above–mentioned purpose can be attained by forming a double hetero structure which comprises a $(\text{AlGa})_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0.51 < \alpha \leq 0.73$) mix crystal via a buffer layer which cancels both stacking fault on a semiconductor substrate.

[0006]As a buffer layer, a $\text{GaAs}_{1-x}\text{P}_x$ mix crystal which carries out lattice matching to a $(\text{AlGa})_{\alpha}\text{In}_{1-\alpha}\text{P}$ mix crystal by the presentation X is used as a material (AlGa), What was changed into graded one from 0 to X having applied to a $(\text{AlGa})_{\alpha}\text{In}_{1-\alpha}\text{P}$ mix crystal from a GaAs substrate using a presentation of this as a semiconductor substrate (AlGa) can be used. Thickness of a $\text{GaAs}_{1-x}\text{P}_x$ mix crystal buffer layer is about tens of micrometers.

[0007]What formed a strained layer superlattice layer as an option with a $(\text{AlGa})_{0.51}\text{In}_{0.49}\text{P}$ mix crystal which carries out lattice matching to a GaAs substrate (AlGa), and a $(\text{AlGa})_{\alpha}\text{In}_{1-\alpha}\text{P}$ mix crystal which produces a stacking fault (AlGa) can be used as a buffer layer.

[0008]Since order arraying structure of group III elements produces a $(\text{AlGa})_{\alpha}\text{In}_{1-\alpha}\text{P}$ mix crystal grown–up by metal–organic chemical vapor deposition, bandgap energy becomes small. Since this order arraying structure is controlled, an impurity can be doped to an active layer or a GaAs inclination board can be used.

[0009]

[Function]Bandgap energy is large at a transited [directly] type, and a $(\text{AlGa})_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0.51 < \alpha \leq 0.73$) mix crystal is raised as an III–V fellows semiconductor material in which the luminous wavelength of a 0.5–micrometer belt is obtained. However, when not carrying out lattice matching of this material to a GaAs substrate but growing up on a GaAs substrate, the means for canceling a lattice

strain is required for it. Therefore, the above-mentioned buffer layer can be considered. In the case of a $\text{GaAs}_{1-x}\text{P}_x$ mix crystal buffer layer, the presentation X is gradually changed into a GaAs substrate from 0, it grows up to be it, and is considered as the presentation which carries out lattice matching of the top layer to a $(\text{AlGa})_{\alpha}\text{In}_{1-\alpha}\text{P}$ mix crystal. For example, the presentation X of a $\text{GaAs}_{1-x}\text{P}_x$ mix crystal which carries out lattice matching to the $(\text{AlGa})_{0.7}\text{In}_{0.3}\text{P}$ mix crystal of the presentation 0.7 is 0.4. A lattice strain is cancelable if the substrate which grew the $\text{GaAs}_{1-x}\text{P}_x$ (X= 0-0.4) mix crystal which changed the presentation gradually and set the upper presentation to 0.4 is used on a GaAs substrate. [0010](AlGa) In the case of the strained layer superlattice layer buffer layer of a $(\text{AlGa})_{0.51}\text{In}_{0.49}\text{P}$ mix crystal and a $(\text{AlGa})_{\alpha}\text{In}_{1-\alpha}\text{P}$ mix crystal, It has neither a defect nor distorted influence on the $(\text{AlGa})_{\alpha}\text{In}_{1-\alpha}\text{P}$ mix crystal which confines a lattice strain in this strained layer superlattice layer, and grows up to be the upper part.

[0011]Thereby, the $(\text{AlGa})_{\alpha}\text{In}_{1-\alpha}\text{P}$ mix crystal which has a luminous wavelength of a 0.5-micrometer belt on a semiconductor substrate (AlGa) can be grown up.

[0012]In the $(\text{AlGa})_{0.7}\text{In}_{0.3}\text{P}$ mix crystal grown-up by metal-organic chemical vapor deposition on the $\text{GaAs}_{0.6}\text{P}_{0.4}$ mix crystal, the order arraying structure of group III elements generates, In connection with this, it becomes small 70 to 90 meV from the case where bandgap energy is disorderly arraying structure. In order to obtain a shorter oscillation wavelength, generation of order arraying structure must be controlled. As a method effective in controlling order arraying structure and producing laser structure, the method of growing up on the GaAs substrate which doped the impurity to the active layer or to which the substrates face direction inclined from the field (100) was used.

[0013]Although bandgap energy can be substantially enlarged by making an active layer into single quantum well structure or multiple quantum well structure, it poses a problem that order arraying structure arises in a quantum well and a quantum barrier layer. For this reason, it was made to take large quantum level energy by doping an impurity uniformly to quantum well structure, or carrying out an abnormal-conditions dope at a quantum barrier layer, and controlling order arraying structure.

[0014]

[Example]Drawing 1 explains one example of example 1 this invention. First, mixed-crystal semiconductor board 1" which provided buffer layer 1' which changed the n type $\text{GaAs}_{1-x}\text{P}_x$ mix crystal gradually to the presentations 0-0.4 on the n type GaAs substrate 1 which has a field (100) is used, On it The n type (aluminum_yGa_{1-y})_{0.7}In_{0.3}P lightguide 2 (micrometers [d= 1.5], $n_D=1 \times 10^{18} \text{cm}^{-3}$, y= 0.7), The undoping (aluminum_zGa_{1-z})_{0.7}In_{0.3}P active layer 3 (micrometer [d= 0.04-0.08], z= 0), The p type (aluminum_{0.7}Ga_{0.3})_{0.7}In_{0.3}P lightguide 4 (micrometers [d= 1.2], $n_A=5 - 7 \times 10^{17} \text{cm}^{-3}$, y= 0.7), The p type $\text{Ga}_{0.7}\text{In}_{0.3}\text{P}$ buffer layer 5 (micrometer [d= 0.1], $n_A=2 \times 10^{18} \text{cm}^{-3}$), The n type (aluminum_yGa_{1-y})_{0.7}In_{0.3}P current stricture layer 6 (micrometer [d= 0.1], $n_D=2 \times 10^{18} \text{cm}^{-3}$, y= 0) is grown epitaxially by metal-organic chemical vapor deposition at the growing temperature of 700 *. Then, a resist mask (stripe width of 6-8 micrometers) is formed by photo lithography, and etching removal is carried out until it results the layer 6 in the layer 5 by chemical etching. Next, after embedding the p type $\text{Ga}_{0.7}\text{In}_{0.3}\text{P}$ contact layer 7 (micrometers [d= 1-2], $n_A=5 \times 10^{18} - 1 \times 10^{19} \text{cm}^{-3}$) and growing up, the p electrode 8 and the n electrode 9 are vapor-deposited. A cleavage scribe is carried out, it starts in the form of an element, and the element which has a section of drawing 1 is obtained.

[0015]This example has realized laser structure of the 0.5-micrometer belt guided by gain difference. In this element, in the room temperature, threshold current operated at 150-200 mA, and obtained the laser oscillation wavelength of 585-595 nm.

[0016]Drawing 2 explains the other examples of example 2 this invention. As shown in drawing 2, in the manufacturing method of Example 1 between n type $\text{GaAs}_{1-x}\text{P}_x$ mix crystal buffer layer 1' and the n type (aluminum_yGa_{1-y})_{0.7}In_{0.3}P lightguide 2, The superlattice layers 10 which accumulated the n type

Ga_{0.7}In_{0.3}P layer and the n type (aluminum_yGa_{1-y})_{0.7}In_{0.3}P layer (d= 3–5 nm, n_D=1x10¹⁸cm⁻³) are formed. Others are completely the same as that of Example 1. By forming these superlattice layers 10, the crystallinity of the upper lightguide and an active layer and luminous efficiency improved.

[0017]By this example, threshold current has been reduced to 100–150 mA in the room temperature. The laser oscillation wavelength was the same range as Example 1.

[0018]3 figures explain the other examples of example 3 this invention. (100) A field. The strained layer superlattice layer 11 which accumulated the n type Ga_{0.51}In_{0.49}P layer and the n type Ga_{0.7}In_{0.3}P layer (d= 3–5 nm, n_D=1x10¹⁸cm⁻³) is formed on GaAs substrate 1 which it has. Then, an element is produced by the completely same method as Example 1.

[0019]Also by this example, the same effect as Example 2 was acquired.

[0020]4 figures explain the other examples of example 4 this invention. It grows up to the p type Ga_{0.7}In_{0.3}P buffer layer 5 like Example 1. Then, a SiO₂ stripe mask (d= 0.2–0.4 micrometer, stripe width of 4–6 micrometers) is formed by photo lithography, and the ridge stripe which left 0.2–0.4 micrometer of layers 4 by chemical etching is produced. Selective growth of the n type Ga_{0.7}In_{0.3}P current stricture Kanemitsu absorption layer 12 (micrometer [d= 1], n_D=2x10¹⁸cm⁻³) is carried out with a SiO₂ stripe mask left. Then, etching removal of the SiO₂ stripe mask is carried out, Next, the p type Ga_{0.7}In_{0.3}P contact layer 7 (micrometers [d= 1–2], n_A=5x10¹⁸ – 1x10¹⁹cm⁻³) is embedded, it grows up, and element production is performed like said example.

[0021]According to this example, the stripe geometry guided by refractive index difference could be produced, and the laser beam by which basic horizontal microfiche control was carried out was able to be obtained. In this element, threshold current has been reduced to 80–100 mA in the room temperature. About the laser oscillation wavelength, it was the same range as said example.

[0022]The other examples of example 5 this invention are described below. In the element manufacturing method to said Examples 1–4, it performed 6-x-10⁻¹⁷—1-x-10⁻¹⁸cm⁻³-doping the impurity of a p type or a n type to the active layer 3. Others completely produced the element like said example.

[0023]According to this example, the short wavelength formation of the laser oscillation wavelength in a room temperature was able to be carried out to 565–575 nm.

[0024]The other examples of example 6 this invention are described below. In the element manufacturing method to said Examples 1–4, and it is from a field (100). [the n type GaAs substrate 1] [110][–1–10] a direction — or [1–10][–110] By using for a direction the GaAs substrate which has the field (511) leaning [angle of 15.8 degrees], element production was carried out like said example.

[0025]The short wavelength formation of the laser oscillation wavelength was able to be carried out to 565–575 nm by this example as well as Example 5. Although the GaAs substrate which has a field (511) was used in this example, when it was an inclination board which has an angle up to 54.7 degrees, there is an effect of short wavelength formation rather than Examples 1–4, and the oscillation wavelength of the range which is 565–585 nm was obtained.

[0026]5 figures explain the other examples of example 7 this invention. After growing up to the n type (aluminum_yGa_{1-y})_{0.7}In_{0.3}P lightguide 2 like Example 4, The undoped multiplex quantum well active layer 13. 3–7 nm of thickness. (aluminum_{z1}Ga_{1-z1})_{0.7}In_{0.3}P quantum wells, 9–11 layers of 0 (aluminum_{z2}Ga_{1-z2})_{0.7}In_{0.3}P quantum barriers of 4–8 nm of thickness, 0 < z₁ < z₂ < y is grown up. After this, element production is completely performed like Example 4.

[0027]According to this example, in the room temperature, threshold current could decrease at 50–80 mA, and the laser oscillation wavelength of 540–550 nm was able to be obtained.

[0028]The other examples of example 8 this invention are described below. Although the element was produced like Example 7, the same impurity doping as Example 5 was uniformly performed to the multiplex quantum well active layer 13, or it carried out by becoming irregular to a quantum barrier layer.

[0029]According to this example, short wavelength formation of the laser oscillation wavelength in a room temperature was able to be carried out to 530–540 nm.

[0030]The other examples of example 9 this invention are described below. Although an element is

produced like Example 7, the same inclination board as Example 6 is used, and it is from a field (100). [110] $[-1-10]$ a direction — or $[1-10] [-110]$ The element was produced on the GaAs substrate which has the field (511) leaning [angle of 15.8 degrees] in a direction.

[0031]Also in this example, short wavelength formation of the laser oscillation wavelength in a room temperature was able to be carried out to 530–540 nm like Example 8. From a field (100) $[110] [-1-10]$ a direction — or $[1-10] [-110]$ If it is an inclination board whose angle leaning to the direction is up to 54.7 degrees, it is effective in short wavelength formation.

[0032]In the above-mentioned example, although crystal growth was performed at 700 **, other temperature in the range of 650–750 ** may be sufficient as it.

[0033]

[Effect of the Invention]According to this invention. On a GaAs substrate, a presentation. Via the strained layer superlattice buffer layer by the $\text{GaAs}_{1-x}\text{P}_x$ mix crystal buffer layer or $(\text{AlGa})_{0.51}\text{In}_{0.49}\text{P}$ mix crystal changed into graded one, and a $(\text{AlGa})_{0.7}\text{In}_{0.3}\text{P}$ mix crystal. The $(\text{AlGa})_{0.7}\text{In}_{0.3}\text{P}$ mix crystal with about 1.4% of stacking fault (AlGa) could be grown up with sufficient crystallinity, and defect density and a deformation amount were able to be made small. Thereby, the double hetero-junction by a $(\text{AlGa})_{0.7}\text{In}_{0.3}\text{P}$ mix crystal has been formed. By producing the stripe geometry guided by gain difference or refractive index difference, the laser oscillation of a 0.5-micrometer belt was obtained in the room temperature. By making an active layer into multiple quantum well structure, threshold current has realized the oscillation wavelength of 530–540 nm at 50–80 mA in the room temperature.

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1]It is an element structure sectional view of Example 1 of this invention, Example 5, and Example 6.

[Drawing 2]It is an element structure sectional view of Example 2 of this invention, Example 5, and Example 6.

[Drawing 3]It is an element structure sectional view of Example 3 of this invention, Example 5, and Example 6.

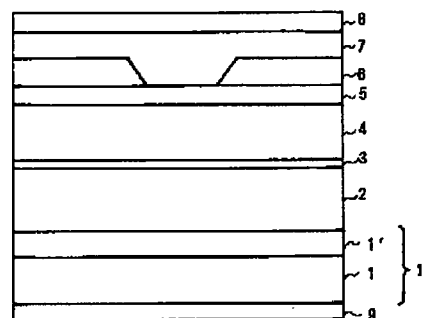
[Drawing 4]It is an element structure sectional view of Example 4 of this invention thru/or Example 6.

[Drawing 5]It is an element structure sectional view of Example 7 of this invention thru/or Example 9.

[Description of Notations]

1 — (100) The n type GaAs substrate which has the field leaning from the field n type GaAs substrate or (100) the field, 1' — The n type $\text{GaAs}_{1-x}\text{P}_x$ mix crystal buffer layer which changed the presentation gradually from 0 to 0.4, 1'' — The mixed-crystal semiconductor board, 2 which are formed in the numerals 1 and 1 — N type $(\text{aluminum}_y\text{Ga}_{1-y})_{0.7}\text{In}_{0.3}\text{P}$ lightguide, 3 — $(\text{aluminum}_z\text{Ga}_{1-z})_{0.7}\text{In}_{0.3}\text{P}$ active layer, 4 — P type $(\text{aluminum}_y\text{Ga}_{1-y})_{0.7}\text{In}_{0.3}\text{P}$ lightguide, 5 — P type $\text{Ga}_{0.7}\text{In}_{0.3}\text{P}$ buffer layer, 6 — N type $(\text{aluminum}_y\text{Ga}_{1-y})_{0.7}\text{In}_{0.3}\text{P}$ current stricture layer, 7 — P type $\text{Ga}_{0.7}\text{In}_{0.3}\text{P}$ contact layer, 8 — p electrode, 9 — n electrode, 10 — N type $\text{Ga}_{0.7}\text{In}_{0.3}\text{P}/\text{n type } (\text{aluminum}_y\text{Ga}_{1-y})_{0.7}\text{In}_{0.3}\text{P}$ superlattice buffer layer, 11 — N type $\text{Ga}_{0.7}\text{In}_{0.3}\text{P}/\text{n type } \text{Ga}_{0.7}\text{In}_{0.3}\text{P}$ strained layer superlattice buffer layer, 12 — N type $\text{Ga}_{0.7}\text{In}_{0.3}\text{P}$ current stricture Kanemitsu absorption layer, 13 — $(\text{aluminum}_{z1}\text{Ga}_{1-z1})_{0.7}\text{In}_{0.3}\text{P}/(\text{aluminum}_{z2}\text{Ga}_{1-z2})_{0.7}\text{In}_{0.3}\text{P}$ quantum well structure.

[Translation done.]



【特許請求の範囲】

【請求項1】半導体基板上に、 $(\text{AlGa})_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0.51 < \alpha \leq 0.73$) 混晶から成るダブルヘテロ構造体を、両者の格子不整を解消するバッファ層を介して形成し、かつ上記ダブルヘテロ構造体の光導波層は $(\text{Al}_y\text{Ga}_{1-y})_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0 < y \leq 1, 0.51 < \alpha \leq 0.73$) から成り、発光活性層は $(\text{Al}_z\text{Ga}_{1-z})_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0 \leq z < y, 0.51 < \alpha \leq 0.73$) から成ることを特徴とする半導体レーザ素子。

【請求項2】上記半導体基板はGaAsから成り、上記バッファ層は $\text{GaAs}_{1-x}\text{P}_x$ から成りかつその組成Xは上記GaAs基板面側を0として膜厚方向に徐々に大きくなっており、上記ダブルヘテロ構造体の光導波層側で該層と格子整合するXとなっている請求項1記載の半導体レーザ素子。

【請求項3】上記半導体基板はGaAsから成り、上記バッファ層は該GaAs基板に対して格子整合する $(\text{Al}_{\beta}\text{Ga}_{1-\beta})_{0.51}\text{In}_{0.49}\text{P}$ ($0 \leq \beta \leq 1$) 層と格子不整を生じる $(\text{Al}_{\beta}\text{Ga}_{1-\beta})_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0 \leq \beta \leq 1$) 層の周期構造からなる歪超格子層から成る請求項1記載の半導体レーザ素子。

【請求項4】上記 $\text{GaAs}_{1-x}\text{P}_x$ 層と上記光導波層との間に、 $\text{Ga}_{\alpha}\text{In}_{1-\alpha}\text{P}$ 層と $(\text{Al}_y\text{Ga}_{1-y})_{\alpha}\text{In}_{1-\alpha}\text{P}$ 層の周期構造からなる超格子層を設けた請求項2記載の半導体レーザ素子。

【請求項5】上記光導波層及び発光活性層の組成 α は0.7である請求項1乃至4のいずれかに記載の半導体レーザ素子。

【請求項6】上記光導波層及び発光活性層の組成 α は0.7であり、上記 $\text{GaAs}_{1-x}\text{P}_x$ 混晶の最上層は組成 $X=0.4$ である請求項2又は4に記載の半導体レーザ素子。

【請求項7】上記GaAs基板の結晶面は、 (100) 面、或は (100) 面から $[110]$ $[-1-10]$ 方向又は $[1-10]$ $[-110]$ 方向に 5.4° までの角度傾いた結晶面、或は (110) 面である請求項1乃至6のいずれかに記載の半導体レーザ素子。

【請求項8】上記発光活性層は、p型またはn型の不純物がドーピングされている請求項1乃至7のいずれかに記載の半導体レーザ素子。

【請求項9】上記発光活性層は、 $(\text{Al}_{z1}\text{Ga}_{1-z1})_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0 \leq z_1 < y$) 単一量子井戸層の両側に $(\text{Al}_{z2}\text{Ga}_{1-z2})_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0 \leq z_1 < z_2 < y$) 光導波層を設けた単一量子井戸構造から成る請求項1乃至7のいずれかに記載の半導体レーザ素子。

【請求項10】上記発光活性層は、 $(\text{Al}_{z1}\text{Ga}_{1-z1})_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0 \leq z_1 < y$) 量子井戸層と $(\text{Al}_{z2}\text{Ga}_{1-z2})_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0 \leq z_1 < z_2 < y$) 量子障壁層を繰り返し設けた多重量子井戸構造から成る請求項1乃至7のいずれかに記載の半導体レーザ素子。

【請求項11】上記発光活性層は、p型またはn型の不

純物が一様にドーピングされている請求項9又は10に記載の半導体レーザ素子。

【請求項12】上記単一量子井戸構造における光導波層にp型またはn型の不純物が変調ドーピングされている請求項9記載の半導体レーザ素子。

【請求項13】上記多重量子井戸構造における量子障壁層にp型またはn型の不純物が変調ドーピングされている請求項10記載の半導体レーザ素子。

【請求項14】上記p型又はn型の不純物濃度は $5 \times 10^{17} \sim 2 \times 10^{18} \text{ cm}^{-3}$ の範囲である請求項8、11、12又は13に記載の半導体レーザ素子。

【請求項15】上記p型の不純物種はZn、Mg又はBeからなる請求項14記載の半導体レーザ素子。

【請求項16】上記n型の不純物種はSi又はSeから成る請求項14記載の半導体レーザ素子。

【発明の詳細な説明】

【0001】

【産業上の利用分野】本発明は、光情報端末或は光情報処理用の光源に適する短波長可視半導体レーザ素子に関する。

【0002】

【従来の技術】従来の短波長可視半導体レーザ素子は、例えば、ジャパン・ジャーナル・オブ・フィジクス 1990年第29巻第L1669頁から第L1671頁 (Jpn J. Appl. Phys. Lett. 29(1990) pp. L1669-L1671) に論じられているように、GaAs基板に格子整合した $(\text{AlGa})_{0.51}\text{In}_{0.49}\text{P}$ 混晶系で実現されており、その室温近傍における連続動作発振波長は 630 nm である。

【0003】

【発明が解決しようとする課題】しかし、室温において $0.5 \mu\text{m}$ 帯の発振波長で動作する AlGaInP 系半導体レーザ素子に関しては報告されていない。

【0004】本発明は、室温において $0.5 \mu\text{m}$ 帯の発振波長で動作する AlGaInP 系半導体レーザ素子を提供することを目的とする。

【0005】

【課題を解決するための手段】上記目的は、半導体基板上に $(\text{AlGa})_{\alpha}\text{In}_{1-\alpha}\text{P}$ ($0.51 < \alpha \leq 0.73$) 混晶から成るダブルヘテロ構造体を、両者の格子不整を解消するバッファ層を介して形成することにより達成できる。

【0006】バッファ層としては、材料として $(\text{AlGa})_{\alpha}\text{In}_{1-\alpha}\text{P}$ 混晶と組成Xで格子整合する $\text{GaAs}_{1-x}\text{P}_x$ 混晶を用い、この組成を半導体基板として用いるGaAs基板から $(\text{AlGa})_{\alpha}\text{In}_{1-\alpha}\text{P}$ 混晶にかけて0からXまでグレーデッドに変えたものを用いることができる。 $\text{GaAs}_{1-x}\text{P}_x$ 混晶バッファ層の膜厚は数十 μm 程度である。

【0007】また別の方法として、GaAs基板に格子整合する $(\text{AlGa})_{0.51}\text{In}_{0.49}\text{P}$ 混晶と格子不整を生じる $(\text{AlGa})_{\alpha}\text{In}_{1-\alpha}\text{P}$ 混晶とで歪超格子層を形成したものをバッファ層として用いることができる。

【0008】また、有機金属気相成長法により成長された $(\text{AlGa})_{0.7}\text{In}_{0.3}\text{P}$ 混晶は、III族元素の秩序配列構造が生じるため、バンドギャップエネルギーが小さくなる。この秩序配列構造を抑制するため、活性層に不純物をドーピングするか又はGaAs傾角基板を用いることができる。

【0009】

【作用】直接遷移型でバンドギャップエネルギーが大きく、 $0.5\mu\text{m}$ 帯の発光波長が得られるIII-V族半導体材料として、 $(\text{AlGa})_{0.7}\text{In}_{0.3}\text{P}$ ($0.51 < \alpha \leq 0.7$) 3) 混晶があげられる。しかし、この材料はGaAs基板には格子整合せず、GaAs基板上に成長するときには格子歪を解消するための手段が必要である。そのため、上記バッファ層が考えられる。 $\text{GaAs}_{1-x}\text{P}_x$ 混晶バッファ層の場合は、GaAs基板に組成Xを0から徐々に変えて成長し、最上層を $(\text{AlGa})_{0.7}\text{In}_{0.3}\text{P}$ 混晶に格子整合する組成とする。例えば、組成0.7の $(\text{AlGa})_{0.7}\text{In}_{0.3}\text{P}$ 混晶に格子整合する $\text{GaAs}_{1-x}\text{P}_x$ 混晶の組成Xは0.4である。GaAs基板上に組成を徐々に変えて上層の組成を0.4とした $\text{GaAs}_{1-x}\text{P}_x$ ($X=0\sim0.4$) 混晶を成長した基板を用いば、格子歪を解消できる。

【0010】 $(\text{AlGa})_{0.51}\text{In}_{0.49}\text{P}$ 混晶と $(\text{AlGa})_{0.7}\text{In}_{0.3}\text{P}$ 混晶との歪超格子層バッファ層の場合は、この歪超格子層に格子歪を閉じ込めて上部に成長する $(\text{AlGa})_{0.7}\text{In}_{0.3}\text{P}$ 混晶に欠陥や歪の影響を及ぼさない。

【0011】これにより、半導体基板上に $0.5\mu\text{m}$ 帯の発光波長を有する $(\text{AlGa})_{0.7}\text{In}_{0.3}\text{P}$ 混晶を成長させることができる。

【0012】また、 $\text{GaAs}_{0.6}\text{Po}_{0.4}$ 混晶上に有機金属気相成長法により成長された $(\text{AlGa})_{0.7}\text{In}_{0.3}\text{P}$ 混晶中にはIII族元素の秩序配列構造が生成し、これに伴ってバンドギャップエネルギーが無秩序配列構造の場合より70~90meV小さくなる。より短い発振波長を得るためには、秩序配列構造の生成を抑制しなければならない。秩序配列構造を抑制しレーザ構造を作製するのに有効な方法として、不純物を活性層にドーピングするか又は基板面方位が(100)面から傾いたGaAs基板上に成長する方法を用いた。

【0013】さらに、活性層を単一量子井戸構造或は多重量子井戸構造とすることによって、実質的にバンドギャップエネルギーを大きくできるが、秩序配列構造が量子井戸及び量子障壁層において生じることが問題となる。このため、量子井戸構造に対して不純物を一様にドーピングするか量子障壁層に変調ドーピングして秩序配列構造を抑制することにより、量子準位エネルギーを大きくとるようにした。

【0014】

【実施例】実施例1

本発明の一実施例を図1により説明する。まず、(100)面を有するn型GaAs基板1上にn型 $\text{GaAs}_{1-x}\text{P}_x$ 混晶

を組成0から0.4まで徐々に変えたバッファ層1'を設けた混晶半導体基板1''を用いて、その上にn型 $(\text{Al}_y\text{Ga}_{1-y})_{0.7}\text{In}_{0.3}\text{P}$ 光導波層2 ($d=1.5\mu\text{m}$, $n_b=1\times10^{18}\text{cm}^{-3}$, $y=0.7$)、アンドープ $(\text{Al}_z\text{Ga}_{1-z})_{0.7}\text{In}_{0.3}\text{P}$ 活性層3 ($d=0.04\sim0.08\mu\text{m}$, $z=0$)、p型 $(\text{Al}_{0.7}\text{Ga}_{0.3})_{0.7}\text{In}_{0.3}\text{P}$ 光導波層4 ($d=1.2\mu\text{m}$, $n_a=5\sim7\times10^{17}\text{cm}^{-3}$, $y=0.7$)、p型 $\text{Ga}_{0.7}\text{In}_{0.3}\text{P}$ バッファ層5 ($d=0.1\mu\text{m}$, $n_a=2\times10^{18}\text{cm}^{-3}$)、n型 $(\text{Al}_y\text{Ga}_{1-y})_{0.7}\text{In}_{0.3}\text{P}$ 電流狭窄層6 ($d=0.1\mu\text{m}$, $n_b=2\times10^{18}\text{cm}^{-3}$, $y=0$)を成長温度700℃において有機金属気相成長法によりエピタキシャル成長する。その後、ホトリソグラフィによりレジストマスク(ストライプ幅6~8μm)を形成し、ケミカルエッチングにより層6を層5に至るまでエッチング除去する。次に、p型 $\text{Ga}_{0.7}\text{In}_{0.3}\text{P}$ コンタクト層7 ($d=1\sim2\mu\text{m}$, $n_a=5\times10^{18}\sim1\times10^{19}\text{cm}^{-3}$)を埋め込み成長した後、p電極8及びn電極9を蒸着する。さらに、劈開スクライプして素子の形に切り出し、図1の断面を有する素子を得る。

【0015】本実施例によって、利得差によって導波される $0.5\mu\text{m}$ 帯のレーザ構造を実現できた。本素子では、室温において閾値電流が150~200mAで動作し、585~595nmのレーザ発振波長を得た。

【0016】実施例2

本発明の他実施例を図2により説明する。実施例1の作製方法において、図2に示すようにn型 $\text{GaAs}_{1-x}\text{P}_x$ 混晶バッファ層1'とn型 $(\text{Al}_y\text{Ga}_{1-y})_{0.7}\text{In}_{0.3}\text{P}$ 光導波層2の間に、n型 $\text{Ga}_{0.7}\text{In}_{0.3}\text{P}$ 層とn型 $(\text{Al}_y\text{Ga}_{1-y})_{0.7}\text{In}_{0.3}\text{P}$ 層 ($d=3\sim5\text{nm}$, $n_b=1\times10^{18}\text{cm}^{-3}$)を積み重ねた超格子層10を設ける。その他は、全く実施例1と同様である。この超格子層10を設けることによって、上層の光導波層及び活性層の結晶性及び発光効率が向上した。

【0017】本実施例によって、室温において閾値電流を100~150mAに低減できた。レーザ発振波長は実施例1と同様の範囲であった。

【0018】実施例3

本発明の他実施例を図3により説明する。(100)面を有するGaAs基板1上にn型 $\text{Ga}_{0.51}\text{In}_{0.49}\text{P}$ 層とn型 $\text{Ga}_{0.7}\text{In}_{0.3}\text{P}$ 層 ($d=3\sim5\text{nm}$, $n_b=1\times10^{18}\text{cm}^{-3}$)を積み重ねた歪超格子層11を設ける。その後、実施例1と同様の方法により素子を作製する。

【0019】本実施例によっても、実施例2と同様の効果を得た。

【0020】実施例4

本発明の他実施例を図4により説明する。実施例1と同様にして、p型 $\text{Ga}_{0.7}\text{In}_{0.3}\text{P}$ バッファ層5まで成長する。その後、ホトリソグラフィによって SiO_2 ストライプマスク ($d=0.2\sim0.4\mu\text{m}$, ストライプ幅4~6μm)を形成して、ケミカルエッチングにより層4を0.2~0.4μm残したリッジストライプを作製する。さらに、 SiO_2 ストライプマスクを残したまま、n型 $\text{Ga}_{0.7}\text{In}_{0.3}\text{P}$ 電流狭窄兼光吸収層12 ($d=1\mu\text{m}$, $n_b=2\times10^{18}\text{cm}^{-3}$)を選択

成長する。この後、 SiO_2 ストライプマスクをエッチング除去し、次に p 型 $\text{Ga}_{0.7}\text{In}_{0.3}\text{P}$ コンタクト層 7 ($d=1\sim 2\mu\text{m}$, $n_A=5\times 10^{18}\sim 1\times 10^{19}\text{cm}^{-3}$) を埋め込み成長して前記実施例と同様に素子作製を行う。

【0021】本実施例によると、屈折率差によって導波されるストライプ構造を作製でき、基本横モード制御されたレーザ光を得ることができた。本素子では、室温において閾値電流を $80\sim 100\text{mA}$ に低減できた。レーザ発振波長に関しては、前記実施例と同様の範囲であった。

【0022】実施例5

本発明の他実施例を以下に説明する。前記実施例1から4までの素子作製方法において、活性層3に対して p 型又は n 型の不純物を $6\times 10^{17}\sim 1\times 10^{18}\text{cm}^{-3}$ ドーピングすることを行った。その他は、全く前記実施例と同様に素子を作製した。

【0023】本実施例によると、室温におけるレーザ発振波長を $565\sim 575\text{nm}$ に短波長化できた。

【0024】実施例6

本発明の他実施例を以下に説明する。前記実施例1から4までの素子作製方法において、n 型 GaAs 基板1に関して (100) 面から [110] [-1-10] 方向又は [1-10] [-110] 方向に角度 15.8° 傾いた (511) 面を有する GaAs 基板を用いることによって、前記実施例と同様に素子作製した。

【0025】本実施例によっても実施例5と同様にレーザ発振波長を $565\sim 575\text{nm}$ に短波長化できた。また、本実施例では (511) 面を有する GaAs 基板を用いたが、 54.7° までの角度を有する傾角基板であれば、実施例1~4よりも短波長化の効果がより、 $565\sim 585\text{nm}$ の範囲の発振波長を得た。

【0026】実施例7

本発明の他実施例を5図により説明する。実施例4と同様にして、n 型 $(\text{Al}_y\text{Ga}_{1-y})_{0.7}\text{In}_{0.3}\text{P}$ 光導波層2まで成長した後、アンドープ多重量子井戸活性層13 (膜厚 $3\sim 7\text{nm}$ の $(\text{Al}_{z1}\text{Ga}_{1-z1})_{0.7}\text{In}_{0.3}\text{P}$ 量子井戸 $8\sim 10$ 層、膜厚 $4\sim 8\text{nm}$ の $(\text{Al}_{z2}\text{Ga}_{1-z2})_{0.7}\text{In}_{0.3}\text{P}$ 量子障壁 $9\sim 11$ 層、 $0\leq z_1 < z_2 < y$) を成長する。この後は、全く実施例4と同様にして素子作製を行う。

【0027】本実施例によると、室温において閾値電流が $50\sim 80\text{mA}$ で低減でき、 $540\sim 550\text{nm}$ のレーザ発振波長を得ることができた。

【0028】実施例8

本発明の他実施例を以下に説明する。実施例7と同様に素子を作製するが、実施例5と同様の不純物ドーピングを多重量子井戸活性層13に対して一様に行うか又は量子障壁層に変調して行った。

【0029】本実施例によると、室温におけるレーザ発振波長を $530\sim 540\text{nm}$ に短波長化することができた。

【0030】実施例9

本発明の他実施例を以下に説明する。実施例7と同様に素子を作製するが、実施例6と同様の傾角基板を用いて、(100) 面から [110] [-1-10] 方向又は [1-10] [-110] 方向に角度 15.8° 傾いた (511) 面を有する GaAs 基板上に素子を作製した。

【0031】本実施例においても、実施例8と同様に室温におけるレーザ発振波長を $530\sim 540\text{nm}$ に短波長化することができた。また、(100) 面から [110] [-1-10] 方向又は [1-10] [-110] 方向に傾いた角度が 54.7° までの傾角基板であれば短波長化に有効である。

【0032】上記実施例では、結晶の成長は 700°C で行なったが、 $650\sim 750^\circ\text{C}$ の範囲にある他の温度でも良い。

【0033】

【発明の効果】本発明によれば、GaAs 基板上に組成をグラデッドに変えた $\text{GaAs}_{1-x}\text{P}_x$ 混晶バッファ層又は $(\text{AlGa})_{0.51}\text{In}_{0.49}\text{P}$ 混晶と $(\text{AlGa})_{0.7}\text{In}_{0.3}\text{P}$ 混晶による歪超格子バッファ層を介して約 1.4% の格子不整のある $(\text{AlGa})_{0.7}\text{In}_{0.3}\text{P}$ 混晶を結晶性良く成長でき、欠陥密度や歪量を小さくできた。これにより、 $(\text{AlGa})_{0.7}\text{In}_{0.3}\text{P}$ 混晶によるダブルヘテロ接合が形成できた。利得差或は屈折率差によって導波されるストライプ構造を作製することにより、室温において $0.5\mu\text{m}$ 帯のレーザ発振を得た。活性層を多重量子井戸構造とすることにより、室温において閾値電流が $50\sim 80\text{mA}$ で $530\sim 540\text{nm}$ の発振波長が実現できた。

【図面の簡単な説明】

【図1】本発明の実施例1、実施例5および実施例6の素子構造断面図である。

【図2】本発明の実施例2、実施例5および実施例6の素子構造断面図である。

【図3】本発明の実施例3、実施例5および実施例6の素子構造断面図である。

【図4】本発明の実施例4乃至実施例6の素子構造断面図である。

【図5】本発明の実施例7乃至実施例9の素子構造断面図である。

【符号の説明】

1…(100) 面 n 型 GaAs 基板又は (100) 面から傾いた面を有する n 型 GaAs 基板、1'…組成を 0 から 0.4 まで徐々に変えた n 型 $\text{GaAs}_{1-x}\text{P}_x$ 混晶バッファ層、1''…符号 1 と 1' により形成される混晶半導体基板、2…n 型 $(\text{Al}_y\text{Ga}_{1-y})_{0.7}\text{In}_{0.3}\text{P}$ 光導波層、3… $(\text{Al}_z\text{Ga}_{1-z})_{0.7}\text{In}_{0.3}\text{P}$ 活性層、4…p 型 $(\text{Al}_y\text{Ga}_{1-y})_{0.7}\text{In}_{0.3}\text{P}$ 光導波層、5…p 型 $\text{Ga}_{0.7}\text{In}_{0.3}\text{P}$ バッファ層、6…n 型 $(\text{Al}_y\text{Ga}_{1-y})_{0.7}\text{In}_{0.3}\text{P}$ 電流狭窄層、7…p 型 $\text{Ga}_{0.7}\text{In}_{0.3}\text{P}$ コンタクト層、8…p 電極、9…n 電極、10…n 型 $\text{Ga}_{0.7}\text{In}_{0.3}\text{P}/\text{n 型 } (\text{Al}_y\text{Ga}_{1-y})_{0.7}\text{In}_{0.3}\text{P}$ 超格子バッファ層、11…n 型 $\text{Ga}_{0.7}\text{I}$

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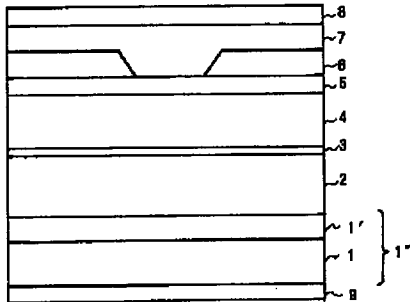
8

$\text{In}_{0.3}\text{P}/\text{n型Ga}_{0.7}\text{In}_{0.3}\text{P}$ 歪超格子バッファ層、1 2...n
型 $\text{Ga}_{0.7}\text{In}_{0.3}\text{P}$ 電流狭窄兼光吸収層、1 3... $(\text{Al}_{z1}\text{Ga}_{1-z1})_{0.7}\text{In}_{0.3}\text{P}$ 量子井戸構造。

* $(\text{Al}_{z1}\text{Ga}_{1-z1})_{0.7}\text{In}_{0.3}\text{P}/(\text{Al}_{z2}\text{Ga}_{1-z2})_{0.7}\text{In}_{0.3}\text{P}$ 量子井戸構造。

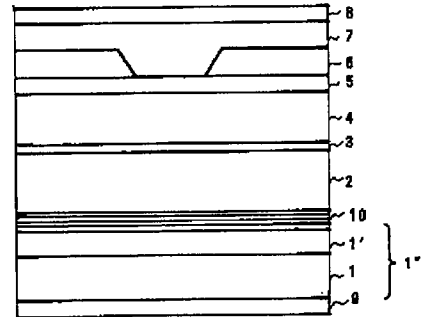
【図1】

図1



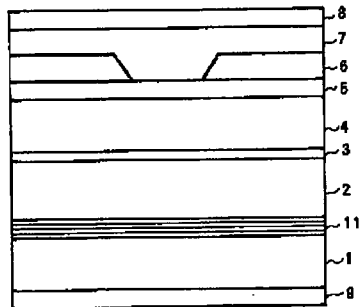
【図2】

図2



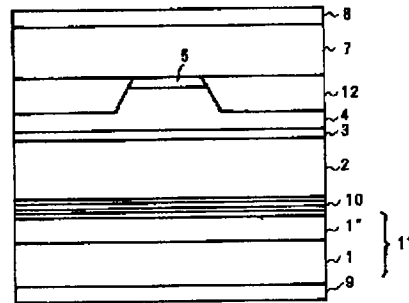
【図3】

図3



【図4】

図4



【図5】

図5

